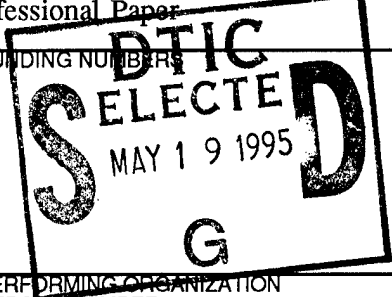


REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
<small>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate only, other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (07804-0188), Washington, DC 20503.</small>				
1. AGENCY USE ONLY (LEAVE BLANK)		2. REPORT DATE 25 January 1995		3. REPORT TYPE AND DATES COVERED Professional Paper
4. TITLE AND SUBTITLE  The New ADS-33 Process: Cautions For Implementation		5. FUNDING NUMBERS		
6. AUTHOR(S)  Herman G. Kolwey				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  DEPARTMENT OF THE NAVY NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION PATUXENT RIVER, MARYLAND 20670-5304				
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		8. PERFORMING ORGANIZATION REPORT NUMBER		
		10. SPONSORING/MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT  APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.				12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words)  This paper presents the author's view that the new ADS-33 test methods must be very carefully applied in practice in order to avoid potential damage or loss of the test aircraft. This opinion comes about after review of several accidents, both fixed and rotary wing, and finding a common thread of frequency related control inputs. A discussion ensued within the AHS Test and Evaluation Committee, bringing forth some seven accidents/incidents involving these these methods. This Technical Note is the final result.				
14. SUBJECT TERMS ADS-33, ASW, fly-by-wire			15. NUMBER OF PAGES 5	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT  UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE  UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT  UNCLASSIFIED	20. LIMITATION OF ABSTRACT  UL	

19950518 042

DTIC QUALITY INSPECTED 5

780-JRW

PUBLIC RELEASE AUTHORIZATION  
NAVAL AIR SYSTEMS COMMAND

CONTROL #: 5SPR-007  
DATE: 1-17-95

From: Public Affairs Office (7.5) 1260, JP1

To: AIR-5302 (Mr. Ade Raghianti)

Subj: The new ADS-33 Process: Cautions for implementation

The attached material has been submitted for public release. Please review the material and complete the form. Please mark any necessary changes by bracketing the material to be changed or deleted and indicating why the change must be made (i.e., security, accuracy, or policy). Do not cross out material - use brackets.

I. Security Review

A-5302

A. Indicate type cognizance your division has, if partial or none, add the cognizant code.

☒ PRIME  
☐ PARTIAL  
☐ NONE

☐ PRIME  
☐ PARTIAL  
☐ NONE

☐ PRIME  
☐ PARTIAL  
☐ NONE

CLEARED FOR  
OPEN PUBLICATION

B. What contract is this release associated with? Contract #: \_\_\_\_\_  
Dated: \_\_\_\_\_

FEB 28 1995

C. Does this document contain critical technology as listed in the Military Critical Technologies List (MCTL)? If so, cite MCTL paragraph. (Copies of the MCTL are available for review from AIR-07T.)

\_\_\_\_ YES ☒ NO

\_\_\_\_ YES \_\_\_\_ NO

\_\_\_\_ YES \_\_\_\_ NO

D. Is this document classified?

\_\_\_\_ YES ☒ NO

\_\_\_\_ YES \_\_\_\_ NO

\_\_\_\_ YES \_\_\_\_ NO

E. If other than UNCLASSIFIED, have you paragraph marked the classified parts and cited supporting rationale?

\_\_\_\_ YES \_\_\_\_ NO

\_\_\_\_ YES \_\_\_\_ NO

\_\_\_\_ YES \_\_\_\_ NO

II. General Review

A. Is the matter, as submitted, factually accurate?

☒ YES \_\_\_\_ NO

\_\_\_\_ YES \_\_\_\_ NO

\_\_\_\_ YES \_\_\_\_ NO

B. Is review outside NAVAIRSYSCOM considered necessary?

\_\_\_\_ YES ☒ NO

\_\_\_\_ YES \_\_\_\_ NO

\_\_\_\_ YES \_\_\_\_ NO

If so, by whom? See below

C. Do you recommend release of the attached material?

☒ YES \_\_\_\_ NO

\_\_\_\_ YES \_\_\_\_ NO

\_\_\_\_ YES \_\_\_\_ NO

D. If the answer to (C) above is NO, check one: (1) \_\_\_\_ Objection is based on security.  
(2) \_\_\_\_ Objection is based on reasons other than security. If (2), indicate why under remarks.

E. Signature and code of person completing this form: Ade Raghianti Date: 1-25-95

F. Remarks: In addition to working @ NAVAIR I am the Chairman of the Test & Evaluation Committee of the American Helo. Society. Mr. Kolwey (the author) is a member of our committee. The enclosed was written with full support & review of the entire AHS T&E committee & has already been reviewed by committee members from all Contractors, NASA, Army, FAA & European Industry. This also was reviewed within NAWCAD.

DEADLINE: 1/24 AIR-07T2: \_\_\_\_\_ AIR-07T3: \_\_\_\_\_

Further review is not required

PLEASE RETURN TO ROOM 1260, JP1-- DO NOT PLACE IN INTRAOFFICE MAIL.

## TECHNICAL NOTES

TECHNICAL NOTES are intended to provide a forum for prompt disclosure of either new developments of a condensed nature or important results of a preliminary nature. Short manuscripts not exceeding one-quarter the length of a full paper qualify for publication in this category. Submission will be formally reviewed by the Editor and published within a few months of receipt.

### The New ADS-33 Process: Cautions For Implementation

Herman G. Kolwey  
4.11.1.4 Competency Leader  
Naval Air Warfare Center Aircraft Division  
Patuxent River, MD 20670

#### Abstract

This paper presents the author's view that the new ADS-33 test methods must be very carefully applied in practice in order to avoid potential damage or loss of the test aircraft. This opinion comes about after review of several accidents, both fixed and rotary wing, and finding a common thread of frequency related control inputs. A discussion ensued within the AHS Test and Evaluation Committee, bringing forth some seven accidents/incidents involving these test methods. This Technical Note is the final result.

#### Introduction

The Army has been working on the new ADS-33 Flying Qualities specification for a while, and now the Navy is starting to show an interest in the new methods and procedures contained in the new specification<sup>1</sup>. While the new methods and tools are extremely useful to the Flying Qualities community, a word of caution must be raised over proper implementation in order to conduct a safe test. Flight testing covers many disciplines. Several of these overlap and must be considered in future test programs (Fig. 1). Since the Structural Demonstrations of our older helicopters were not done with these ADS-33 techniques in mind, there may be a lack of adequate knowledge of the Structural and Dynamic areas of many of our older helicopters as regards control frequency sweeps, which can get the flight test crews into serious trouble. This Technical Note will discuss some of the pitfalls and cite some examples out of both the fixed-wing and rotary wing community identifying

some of the "lessons learned" (some the hard way), which need to be applied to "Frequency Sweep" and similar types of testing. Some will say "What's new! That is the nature of Flight Testing." Maybe nothing is new - You decide.

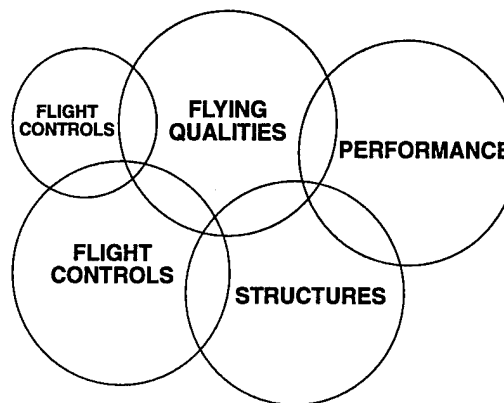


Fig. 1 General Flight Testing  
Structural Demonstrations

Accession For	
NTIS CRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification _____	
By _____	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

A paper presented at an AHS Specialist Meeting in 1988 addressed the Navy's approach to having the contractor conduct, with Navy witnessing, the Structural Demonstration as part of the development process for a new helicopter. Ref. 2 contains the details, but for purposes of this discussion, the points to be made are that: the aircraft is instrumented for structural parameters; structural engineers are monitoring Do Not Exceed (DNE) limit loads on the telemetry ground station; they are conducting a systematic buildup, one parameter at a time; and, they are prepared to invoke the "Knock-it-off" call that will eventually come. Questions regarding Flying Qualities and Performance are raised and, of course accounted for, but they are secondary to the structural test. Fig. 2 characterizes this situation.

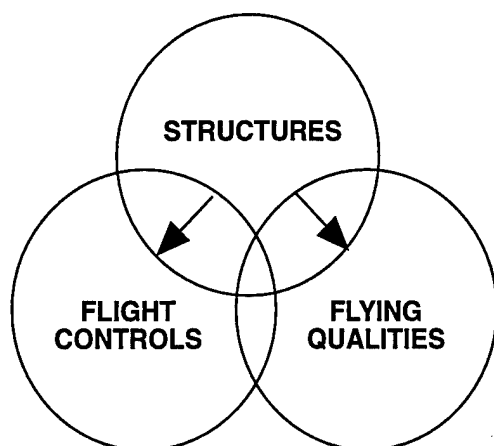


Fig. 2 Structural Demonstration

#### Flying Qualities Testing

In the past, flying qualities testing has been done with little regard for structural considerations because they, for the most part, were not that important. Not so any more. With the frequency sweep testing methods of ADS-33, not only does one need to learn new analysis techniques in the Frequency Domain (Bode Plots, Phase Gain Margins, and others - long-standing tools of the flight controls engineers), we must be intimately aware of the structural DNE limits of the aircraft and have them instrumented and monitored, if necessary. Fig. 3 characterizes our new situation and poses the question we must ask. We must be aware of the structural results of the dynamics modes of the airframe, engine, and main and tail rotor systems as well. If you don't believe these words, read the example Case Histories in the following section.

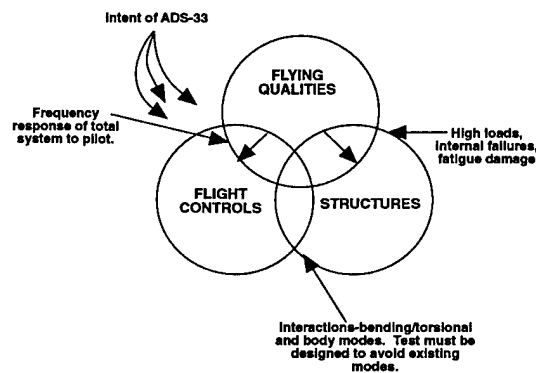


Fig. 3 ADS-33 Flying Qualities Test

#### Case Histories

1. A fixed-wing strike fighter was evaluating the structural adequacy of a new store mounted on a wing station. They were exciting the "short period" mode and were on-frequency by pumping the stick longitudinally at  $\pm 1$  inch displacement when some form of failure occurred associated with the longitudinal control system. The aircraft pitched nose down and crashed. The most likely failure scenario involves bending/breakage or a disconnect of the longitudinal control rod.
2. A fixed-wing Anti-Submarine Warfare (ASW) airplane was being used to collect data for a simulator using rudder frequency sweep methods. Prior to test, a search for sideslip limits was conducted among the flight clearances which supposedly defined limitations for flight and design limits, but no limitations on sideslip were found. It was also believed that harmful lateral loads on the fin could not be generated, since the airplane incorporated a means to hydraulically limit rudder deflection as a function of airspeed. During a rudder frequency sweep at high airspeed, the vertical tail failed, resulting in loss of control and breakup of the airplane. The crew ejected and the airplane crashed. Post-mishap review revealed that references to sideslip limits, which were part of early developmental testing, had been dropped from recent flight clearances. Further, high-speed "dynamic" yaws conducted during structural demonstration tests, did not generate the worst case dynamic loads because they were done using only step inputs.
3. One contractor's helicopter was being tested at another contractor's plant. Permission was requested to seek information from the airframe manufacturer, in order to conduct safe testing. Permission was denied by the project sponsor. In the process of

doing frequency sweeps in roll in a hover, an aluminum shear pin in the lateral cyclic was sheared, reverting aircraft control to the "fly home" minimum control fly-by-wire backup system with a control input in. The aircraft rolled over and crashed: the crew survived. Subsequent discussions between the manufacturer and the testers revealed that they also had an occurrence of shear pin failure in their testing in forward flight flying safely home. In their testing since the incident, they routinely substituted steel shear pins to prevent inadvertent pin shearing during the test.

4. A Navy test plan was written and approved as part of a new engine installation on an old airframe. As part of the test, it was planned and APPROVED to do collective frequency sweeps. The contractor denied permission for the test team to do the planned test citing lack of knowledge of what the dynamics and structural effects of the rotor system and airframe would be as no such tests had been done on the airframe during its 30 year testing history.

5. A low/omni directional airspeed system was mounted above the rotor on a standpipe on an ASW helicopter by the Navy. Inspection after a flight revealed that several mounting bolts on the sensor head had broken. One comment heard was "Install bigger bolts". An input from an avionics engineer about the configuration (weight of the sensor head cantilevered above the upper bearing at 1/2 of the distance between the upper and lower bearings of the standpipe, along with "Good Lord, I can't build an oscillator with that little damping" about the "thump test" time history), led to analysis of the mechanical magnification ratio which turned out to be about 5.5 (Fig. 4). Nothing except "normal" flying had been done on the aircraft to that point. Subsequent lowering of the sensor head and adding mass below it reduced the magnification ratio to around 2 for safe completion of the test without increasing the bolt size.

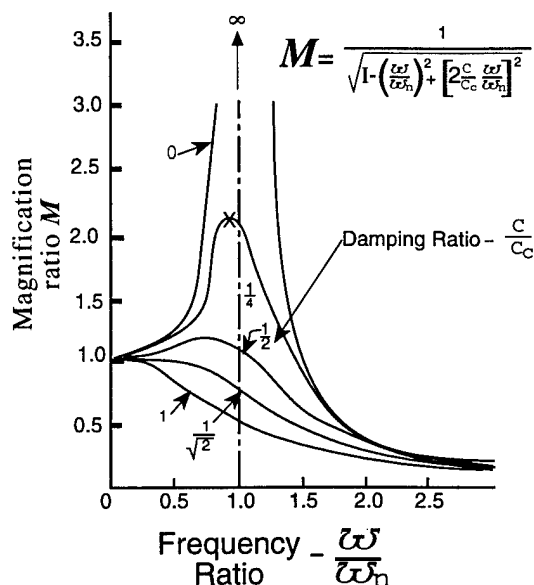


Fig. 4 Magnification Ratio as a Function of the Impressed Frequency Ratio for Various Amounts of Damping

6. Finally, in ADS-33 testing reported by the Army in Ref. 3, an incident involving an OH-58 is worthy of review. This test was done correctly in that a systematic buildup was done. It was instrumented for structural loads and monitored via Telemetry. The aircraft was cycled with frequency sweeps on the ground before flying. The flight had a chase. When the frequency sweep test was conducted, the helicopter encountered a resonance of the mast-mounted sight. What is interesting about this case is that the pilots didn't feel the resonance and the telemetry parameters did not build up rapidly enough to elicit a "knock-it-off" call from the Telemetry Room. The chase pilots SAW THE DEFLECTION and provided the "knock-it-off" call.

#### What's the Point

We are entering a new interdisciplinary era of testing with ADS-33, in which the Flying Qualities engineers and pilots need to be much smarter about testing than they were in the past. All of the examples above, except #5, involve a flying quality test where control inputs or frequency sweeps were done, in which STRUCTURAL failures occurred, or could have. Frequency-sweep testing has the potential to generate higher loads than those maneuvers of the structural demonstration in our older airframes. The ADS-33 Users Guide (Ref. 8) addresses the Operational Flight Envelope (OFE) for mission maneuvers and the Service Flight Envelope (SFE) based on the helicopter's limits. In our present qualification system, the Structural Demonstration provided the safe clearance for all maneuvers to be

The diagram consists of two concentric circles. The inner circle is labeled "Service Flight Envelope (SFE) (Demonstrated during structural demo.)". The outer circle is labeled "Operational Flight Envelope (OFE)". An arrow points from the OFE label to the outer circle, and another arrow points from the SFE label to the inner circle.

It is clear that we must borrow from the rigors of a Structural Demonstration to do Flying Qualities testing safely. This includes instrumenting pertinent parameters with monitoring on telemetry, knowledge of the airframe structural limits and "threat frequencies" (Fig. 6, Ref.4), a chase aircraft, and careful buildup of control inputs in both magnitude and frequency. A buildup must be done starting with static then dynamic ground tests. Only after these are done should flight tests be contemplated. Small

## Conclusion

1. Frequency Sweep test techniques are useful and necessary for the next generation specification requirement.

2. Frequency Sweep techniques need not present any greater flight risk when employed with proper preparation, buildup, and analysis.

### Summary of Testing Conclusions

1. "1)\* Frequency domain flight testing requires careful planning and real time monitoring of potential excited modes to avoid structural damage."<sup>6</sup>
2. "2) Model activity can be extracted from the frequency response results."<sup>6</sup>
3. "5) Emerging aircrew and management concerns surrounding risk levels associated with frequency domain and mission maneuver testing warrant continued emphasis as experience is gained."<sup>6</sup>
4. "3) Frequency domain flight testing requires careful planning and real time monitoring to prevent possible structural damage."<sup>3</sup>
5. "5) A combination of establishing a pre-determined cutoff frequency, realtime loads and input monitoring, limiting the magnitudes of inputs, and pilot-engineer ground training may significantly reduce the potential for damage during piloted frequency sweeps."<sup>3</sup>
6. "6) Pilot and engineer training is essential prior to conducting frequency sweep tests."<sup>3</sup>
7. "7) Piloted frequency sweeps yield much better quality data than computer generated sweeps since the pilot can maintain the trim condition with uncorrelated off-axis inputs."<sup>3</sup>
8. "15) Training in recovery from unusual attitudes is very important for many maneuvers. Training should be conducted in an aerobatic airplane and helicopter if possible."<sup>3</sup>
9. "17) .... a flight test manual needs to be written to cover flight test techniques for ADS-33 compliance testing. This should be an out-growth of the recommended government/industry/university working group on ADS-33 flight test concerns."<sup>3</sup>
10. " .... Modeling of rotor dynamics remains the most critical area of investigation."<sup>4</sup>
11. "The flexible fuselage can be adequately represented by a set of linear second-order differential equations; however, the appropriate mode shape data are highly subject to the forcing condition."<sup>4</sup>
12. "2. The frequency-sweep technique has been

successfully demonstrated on the Bell 214ST helicopter using the following procedure: ...."<sup>7</sup>

**\*Refer to the item numbers contained in each reference.**